

ARIZONA GAME AND FISH DEPARTMENT

RESEARCH BRANCH
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CHARACTERISTICS OF AN EAST-CENTRAL ARIZONA BLACK BEAR POPULATION

A Final Report

ALBERT L. LeCOUNT
September 1990

FEDERAL AID IN WILDLIFE
RESTORATION PROJECT



Arizona Game and Fish Department Mission

To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft recreation for the enjoyment, appreciation, and use of present and future generations.

Arizona Game and Fish Department
Research Branch

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Project W-78-R

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Characteristics of an East-Central Arizona Black Bear Population

Albert L. LeCount

Abstract: Characteristics of a black bear (*Ursus americanus*) population were studied in the White Mountains of northeastern Arizona from 1986 through 1989. Ninety-four individual bears were tagged (37 adults, 23 subadults, 34 cubs). Minimum population size, based on captured adults and subadults, was 32 animals, or 1 bear/2.7 mi², 62% of which were adults. Mean age of this population was 4.9 years, with adult males averaging 4.4 and adult females 5.6 years, respectively. Reproductive data indicated that the average age of first cub production was 4.5 years, with females producing cubs in a synchronous alternate year pattern. Annual survival and mortality rates indicated that the population was being over-harvested. Cubs experienced 21% annual mortality, most of which was due to predation by mountain lions (*Felis concolor*) and bears, and adults experienced 15% annual mortality, primarily because of hunting. This mortality affected recruitment by reducing the number of breeding age females in the population and by reducing the number of cubs available for replacement. Management options are presented.

INTRODUCTION

Black bears (*Ursus americanus*) occur throughout North America from the deciduous forests of the East to the coniferous forests of the West. In Arizona they occur over most of the north and eastern half of the state in habitats ranging from upper Sonoran desert to spruce/fir forest.

Even though black bears are widespread in Arizona, little management effort was given to them until 1968. Before this, the only management information collected was the annual harvest of bears from each Game Management Unit (LeCount 1982a). This information alone made it impossible for managers to effectively evaluate whether their bear harvests were adequate or excessive.

In 1968, the Arizona State Legislature, with the urging of the Arizona Game and Fish Department and conservation organizations, promoted the black bear to big game status. This legislative change increased public interest in bears and dictated the collection of more information on bears, such as population sizes, sex and age ratios, and reproductive rates (LeCount 1982a).

Researchers in other states have shown that such information is essential if bear populations are to be properly managed. These data, when combined with harvest information, make it possible for managers to establish management strategies that preclude overexploitation of populations (Erickson et al. 1964, Jonkel and Cowan 1971, McIlroy 1972, Kemp 1972, Poelker and Hartwell 1973, Lindzey and Meslow 1977, Beecham 1980, Hugie 1982,

Young and Ruff 1982, Rogers 1987).

In 1973, the Arizona Game and Fish Department initiated a series of research studies to determine black bear population characteristics in various vegetation types within Arizona's black bear range. Two of these studies have been completed: one in the chaparral and oak/woodland areas of central Arizona (LeCount 1982b, LeCount et al. 1984), and another in the pine and mixed-conifer areas along the Mogollon Rim of north-central Arizona (LeCount 1987, Molloy et al. 1989). This report contains information from the third in this series of studies. The objectives of this study were to investigate the following items.

- The density of bears on a mixed conifer, spruce/fir study area in the White Mountains of east-central Arizona.

Justification: The White Mountains of northeastern Arizona produce over 20% of the statewide bear harvest (LeCount 1982a), yet it is not known how many bears inhabit this portion of the state. Without this information, wildlife managers have no way of knowing if current harvest rates are adequate or excessive.

- The sex and age ratios of a White Mountain bear population.

Justification: When bears are born, sex ratios are close to 50:50, but because of dispersal of young males and differential vulnerability between various sex and age classes, populations hunted at various intensities can have different sex and age ratios

(Bunnell and Tait 1985). By examining the sex and age ratios of a population, one can gain insight into the effectiveness of past management strategies.

- The reproductive and harvest rates of a White Mountain bear population.

Justification: Most wildlife managers attempt to manage bears on a sustained yield basis. To do this, the manager needs to know how many animals are dying each year and how many are being recruited into the population. In the past, the only portion of this equation that the manager knew was the number of animals being harvested annually. No information was available on natural mortality or recruitment. As a result, managers had a difficult time determining whether a population was being managed on a sustained yield basis.

STUDY AREA

The 87 square mile study area was located in the White Mountains of northeastern Arizona, near the Arizona/New Mexico border (Fig. 1). Topography was dominated by steep slopes and deep canyons, with elevations ranging from 6,800 to 9,300 ft.

Precipitation occurred in a summer/winter pattern. About half the average annual total of 19.3 in fell in the form of afternoon thunder-showers between the first week in July and the middle of September. Most of the remaining moisture occurred in the form of snow as winter storms move eastward across Arizona from November through March. Snow accumulations reached several feet in depth at higher elevations. Temperatures ranged from summer highs of 70 to 80 F to winter lows of approximately 10 F (Sellers and Hill 1974).

Plant communities on the study area were Rocky Mountain Montane Conifer Forest and Rocky Mountain Subalpine Conifer Forest (Brown et al. 1979). Several vegetation associations occurred within each of these communities. The most abundant vegetation associations were mixed conifer, which was dominated by varying amounts of Douglas fir (*Pseudotsuga menziesii*), and white fir (*Abies concolor*). These associations occurred be-

tween 8,000 and 9,000 ft and dominated the study area. Elevations below approximately 8,000 ft were covered by ponderosa pine (*Pinus ponderosa*) associations. Areas above approximately 9,000 ft were characterized by spruce/fir forest dominated by Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), and subalpine fir (*Abies lasiocarpa*). Gambel oak (*Quercus gambelii*) was found throughout the ponderosa pine and lower elevation mixed conifer areas, and aspen (*Populus tremuloides*) occurred in the higher mixed-conifer and spruce/fir zones. Scattered throughout all vegetation communities were small wet meadows locally known as "cienegas."

The entire study area was located within the Apache Sitgreaves National Forest. Major land uses included timber production, livestock grazing, and recreation. Timber harvest and livestock grazing occurred throughout the spring, summer, and fall—recreation throughout the year. Hunting was the most popular form of fall recreation with the bear season running before, and concurrently with, mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), and turkey (*Meleagris gallopavo*) seasons.

METHODS

Capture and Telemetry

Bears were captured each summer from 1986 through 1989, using Aldrich foot snares, and were immobilized with sernylan (phencyclidine hydrochloride). An attempt was made to capture every adult animal on the study area by dividing the area into four quadrants. Each quadrant was sampled using 12 to 15 snares for a 2- to 4-week period from May through August. During the 4 years of study, each quadrant was sampled twice.

Each captured bear was weighed, measured, and tagged with a plastic ear tag in each ear for subsequent identification. A first premolar was also extracted, and age was estimated by the cementum annuli technique (Stoneberg and Jonkel 1966). Radio transmitter collars were attached to 33 animals exceeding 1 year of age. All radio collars were equipped with a movement sensor that indicated

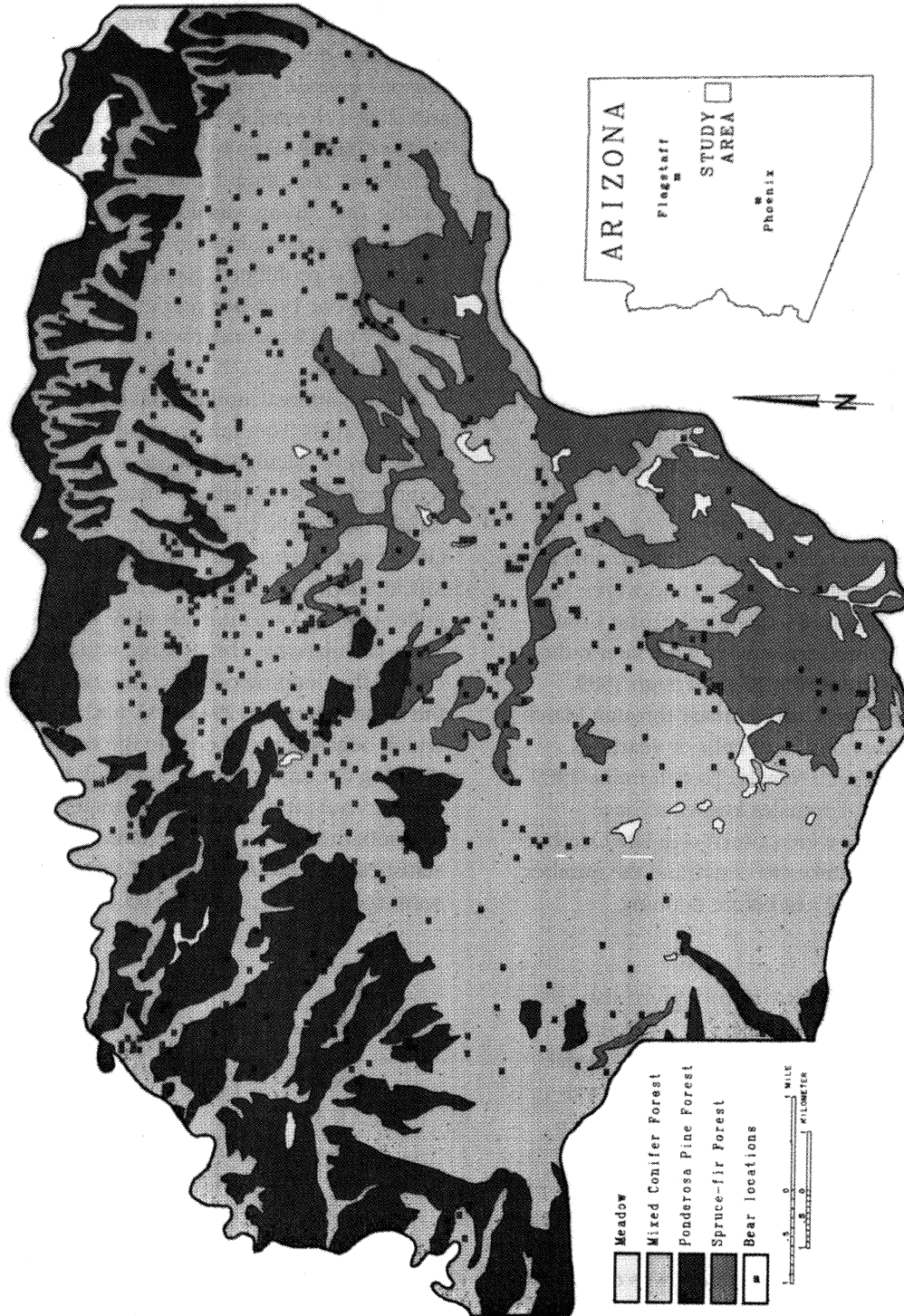


Figure 1: GIS generated map showing four vegetation types and female black bear locations within the White Mountain study area, Arizona, 1987-89.

possible mortality by doubling the pulse rate if collar did not move for 4.5 hours. Subsequent radio locations were made by radio tracking from the ground and aircraft.

Population Estimates

A minimum estimate of population size at the beginning of the study was derived from the actual number of adults and subadults captured. For this estimate, only adults old enough to be adults at the beginning of the study were considered (e.g., 1986 >3, 1987 >4, 1988 >5, 1989 >6 years of age). For comparative purposes, an effort was also made to statistically estimate population size with techniques used in other Arizona black bear studies (LeCount 1982b, 1987). Unfortunately, model criteria could not be met because of the short duration of the study and the death of tagged bears while the study was in progress.

Reproduction and Natality

All females were examined at the time of capture for evidence of estrus and were assigned a rating of 0 to 4 (Jonkel and Cowan 1971). Instrumented females were later radio tracked to dens. From 1987 through 1989, dens were visited from January through March to record the number of cubs or yearlings denned with each female. To determine 1989 cub survival, all females known to have produced cubs were observed in late October and early November to determine the number of cubs still alive just before denning.

Mortality

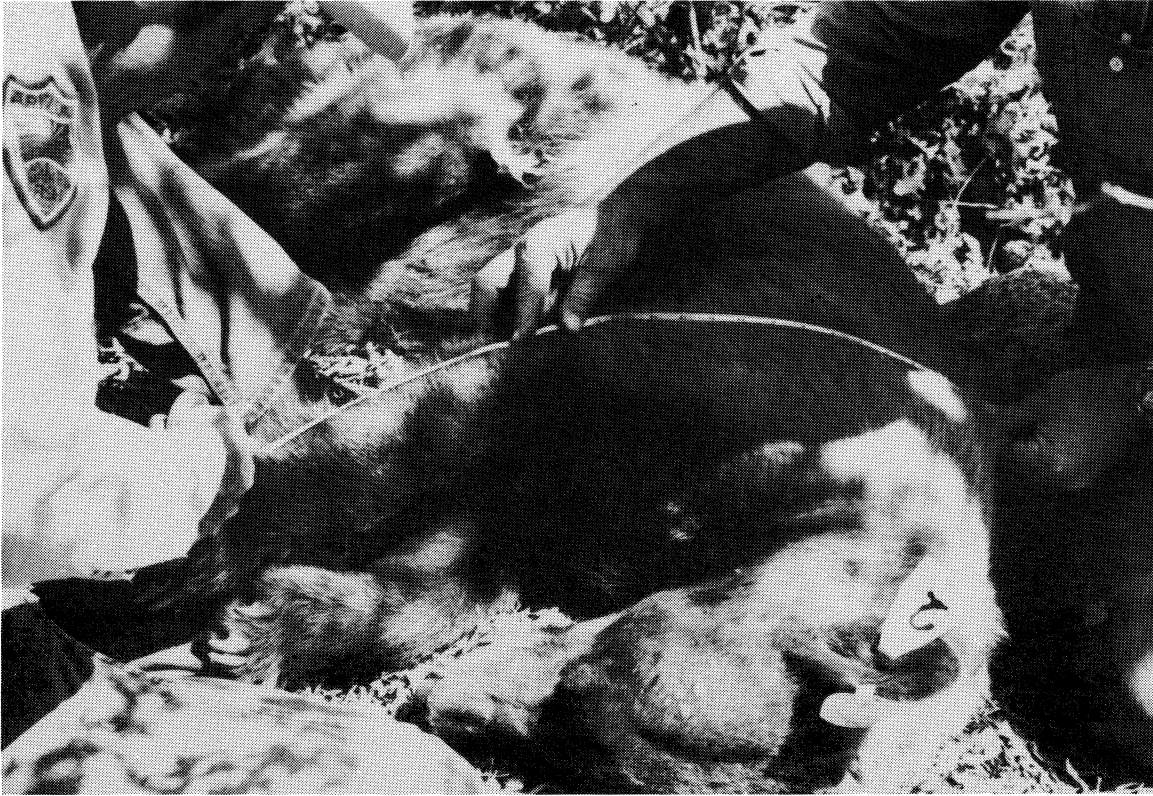
During den visits, 26 cubs were also equipped with radio collars to determine causes of cub mortality. If a mortality signal were detected, the collar immediately was located, and the site was examined for evidence of a carcass and cause of death. Any carcasses retrieved were sent to Southwest Veterinary Diagnostics, Inc. Phoenix, Arizona, for necropsy.

Hunting-induced mortality was determined through return of ear tags and radio collars, and through information reported on hunter checkout forms that the hunter was required to submit to the Arizona Game and Fish

Department. In situations where the exact kill site could not be determined from the information provided, the hunter was telephoned for more specific information.

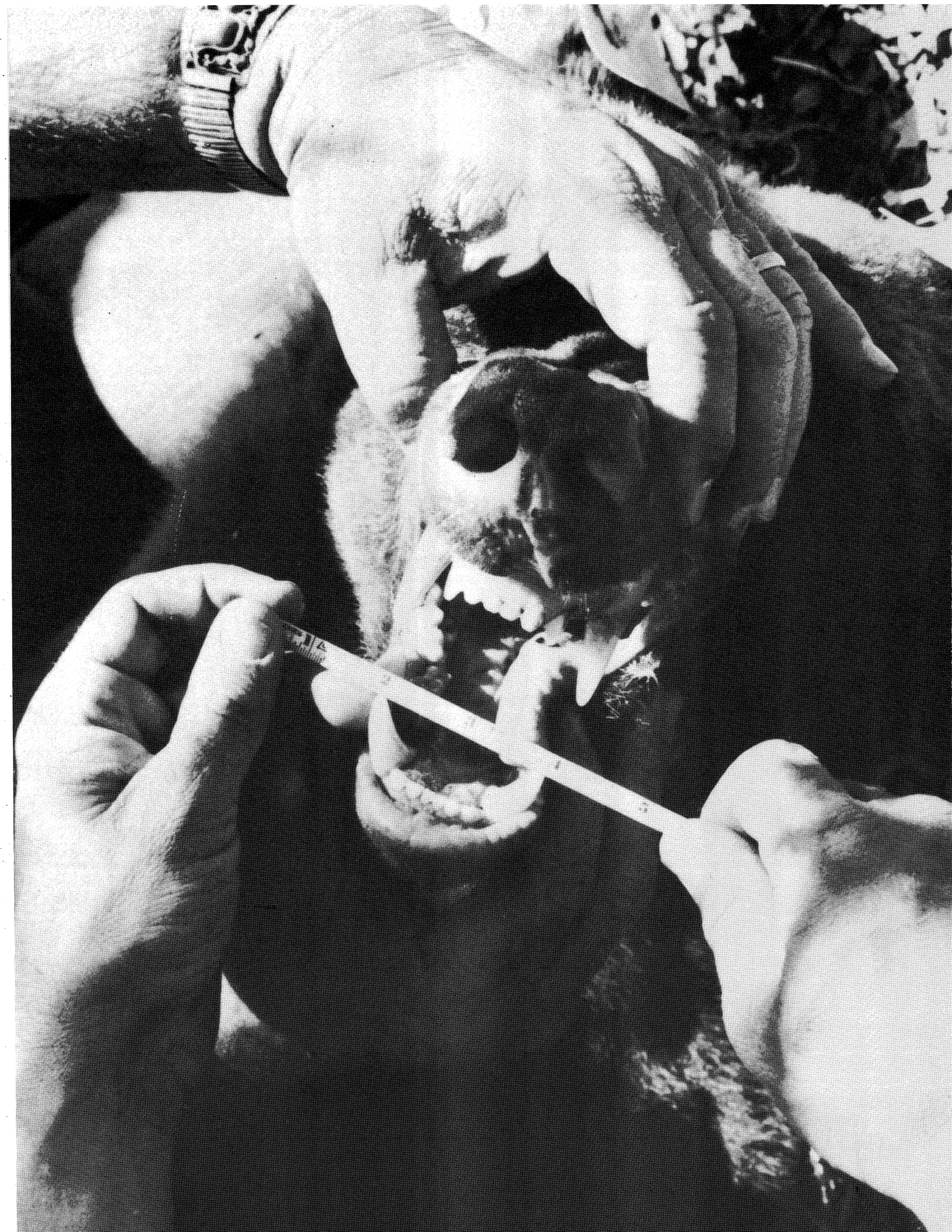
Hunting seasons occurred in Wildlife Management Unit 27, which encompassed the study area, during each year of the study. Seasons opened approximately September 1 and closed November 30. In 1986 and 1987, bears could be taken by a variety of hunting techniques including the use of dogs and baiting, but baiting was limited to the first 7 days of the season. In 1988 and 1989, the use of baits was prohibited. Each hunter was limited to one bear per year and was required to notify the Department within 10 days after making a kill.

Daily, interval, and annual survival and mortality rates from hunting and nonhunting causes were calculated for the adult and cub segments of the population using the techniques developed by Trent and Rongstad (1974) and were modified into the program MICROMORT (3.1) designed by Heisey and Fuller (1985). Two intervals were used in these calculations: nonhunting, which included the denning period to the beginning of the hunting season (294 days), and hunting, which began September 1, to the onset of denning (71 days). Annual subadult mortality and survival rates were not calculated because few subadults were radio collared. For all statistical procedures, levels of significance were considered to be $P < 0.05$.



Biologists measuring chest circumference for correlation with body weight.

*Following Page:
One of the measurements taken from each captured
bear; canine teeth width.*



RESULTS

Population Size and Density

During the 4 years of study, 60 individual black bears (37 M, 23 F) were captured 130 times. Thirty-four (16 M, 18 F) additional bears also were tagged as cubs or yearlings in winter dens. Of the 60 bears captured during the study, 27 (14 M, 13 F) were at least 3 years old at the beginning of the study. Also, each year an average of five new subadults was captured, indicating that at least that number of subadults was present. Combining these two figures suggests that in 1986 at least 32 bears >1 year old, or 1 bear/2.7 mi², existed on the study area. Also, undoubtedly, a number of cubs were present but were not included in the population estimate because the cubs rely on their mothers for survival and are not a self-sustaining portion of the population. This population density is similar to bear densities found in two areas in central Arizona, and in most areas of the U.S. and Canada, but is much higher than the density found in coniferous forest north of the Mogollon Rim in north-central Arizona (Table 1).

This population estimate is based only on animals actually captured, and no capture technique catches all animals present; therefore, it might be argued that actually there are

a higher number of bears occupying the study area than the minimum population estimate indicates. Certainly there are more than the minimum, but capture and radio tracking data tend to indicate that this number cannot be a great deal higher.

Of the two segments of the population making up the estimate, probably the subadult portion is the most underestimated. This underestimation is because subadults, primarily males, tend to ingress and egress continually from the population as they search for places to establish permanent home ranges. Therefore, it is always possible to capture new untagged animals that have recently moved into the area, or not to capture previously untagged animals that move out. How many additional subadults might be on the study area beyond the average of five sampled each year is not known, but the number cannot be a great deal higher or more would have been captured each year because the area was saturated with snares.

In contrast, adults are usually permanent residents in an area. LeCount and Yarchin (1990) found that this was especially true for adult females because their home ranges were smaller than their male counterparts and a larger portion of their home range fell within

Table 1. Black bear densities in various areas of North America expressed as one bear/X mi².

Location	Reference	Mi ²
Alaska	McIlroy 1972	0.1
Washington	Lindzey and Meslow 1977	0.3
Idaho	Beecham 1980	0.5
Alberta	Young and Ruff 1982	0.6-1.0
Washington	Poelker and Hartwell 1973	0.7
Montana	Jonkel and Cowan 1971	0.8-1.9
Alberta	Kemp 1972	1.0
Arizona (southeast)	Waddell and Brown 1984	1.2-1.6
Arizona (central)	LeCount 1982	1.3
Arizona (south of Mogollon Rim)	Le Count 1987	1.4
Maine	Hugie 1982	1.8-3.3
Minnesota	Rogers 1987	1.9
Arizona	This study	2.7
Michigan	Erickson et al. 1964	3.9
Arizona (north of Mogollon Rim)	Le Count 1987	6.5

the boundaries of the study area. LeCount and Yarchin (1990) further documented that adult males, with their larger home ranges, spend more time off the study area. Therefore, some males were not as susceptible to capture operations because they spent a considerable amount of time in portions of their home ranges that fell outside the study area. With enough time, however, most individuals of both sexes should be captured, which would be indicated by the increasing number of trap nights needed to capture a new unmarked adult.

In this study the increasing number of trap nights needed to capture a new adult indicated that most adult females had been tagged (Table 2). In the first year of study it took only 64 trap nights to capture a new adult female, but by 1989 it took almost 300 trap nights. With males, probably more remained untagged at the end of the study than females as indicated by the fluctuations in the number of trap nights needed to capture a new adult male (Table 2). However, because only three new individuals were captured in each of the last two years of study, this number could not have been high.

Age Structure

The percent of adults and subadults present in a population indicates the degree of

hunter exploitation the population has received. Several authors have indicated that in unhunted, or lightly exploited populations, adults make up approximately 70% of the animals present; whereas, in heavily exploited populations, adult numbers are reduced to 60% or less (Kemp 1976, Beecham 1980, Kolenosky 1986, LeCount 1987, 1982a, Rogers 1987). In this study, 62% of the bears captured were adults. This percentage is near that found for heavily exploited populations (Table 3).

The mean age of the entire population (excluding cubs) also is a measure of the relative degree of harvest. As bear populations are hunted, adult males are removed first. Adult males are the most vulnerable segment of the population because they use more open habitat and move about more than females or subadult males (Bunnell and Tait 1985). These adult males are then replaced by subadult males ingressing from other areas (Bunnell and Tait 1981). Thus, heavily exploited populations contain a higher percentage of young males, which reduces the overall average age of the population (Bunnell and Tait 1981).

In this study, mean ages for bears >1 year old were 4.4 (SE = 0.47) years for males, 5.6 (SE = 0.79) years for females, and 4.9 (SE = 0.42) for all bears. These mean ages compare

Table 2. Number of adult male and female black bears captured per trap night on the White Mountain Study Area, Arizona, 1986-1989.

Year	New Adults Captured ^a	Trap Nights	New Adult/ Trap Night
ADULT FEMALES			
1986	6	385	65
1987	3	506	169
1988	3	616	205
1989	1	291	291
ADULT MALES			
1986	1	375	375
1987	7	514	73
1988	3	616	205
1989	3	295	98

^aOnly animals that were adults at the beginning of the study were considered as new adults (e.g. 1986>3 yrs., 1987>4 yrs., 1988>5 yrs., 1989>6 yrs.).

closely to the 3.5 and 4.5 years found in heavily exploited populations in Ontario (Kolenosky 1986) and above the Mogollon Rim in north-central Arizona (LeCount 1987), but are lower than the mean ages for all bears of 5.5 below the Mogollon Rim in north-central Arizona (LeCount 1987) – 8.1 in central Arizona (LeCount 1982b) and 8.8 in California (Keay 1990).

Sex Ratios

Cub sex ratios normally do not vary significantly from the expected 50:50 (Jonkel and Cowan 1971, Kemp 1972, Young and Ruff 1982). Adult and subadult sex ratios, however, may vary because adult males travel more extensively than adult females and are, therefore, more vulnerable to hunting (Rogers et al. 1976, Lindzey and Meslow 1977, Beecham 1980, Young and Ruff 1982). Therefore, as a population is hunted adult males are removed at a higher rate than adult females. These males are replaced by more subadult males than adult males removed, thus producing sex ratios weighted towards males (Kemp 1976, Young and Ruff 1982). In this study 62% of all bears captured were males (Table 3), but neither adult ($\chi^2 = 0.474$, 1 df), subadult ($\chi^2 = 2.908$, 1 df), or cub ($\chi^2 = 2.500$, 1 df) sex ratios varied significantly from the expected 50:50.

Reproduction and Natality

Sixteen adult females were captured 21 times. In 19 of these captures, the female was not accompanied by cubs-of-the-year; therefore, she was examined for evidence of estrus. The earliest observation of estrus was May 28 and the latest was July 22. The peak of the breeding season appeared to be from early June to mid-July, when 88% of all captured females was in estrus (Table 4). This peak was similar to that observed in populations in north-central Arizona (LeCount 1987) but was slightly later than that observed in central Arizona (LeCount 1984). This trend is also consistent with dates found elsewhere in the United States (Lindzey and Meslow 1977, Alt 1982, Graber 1982, Rogers 1987).

None of the 7 subadult females captured were observed in estrus. Of 5 radio collared subadult females monitored during the study, 2 were killed by hunters before reaching maturity. Of the remaining 3, (Nos. 189, 192, 196) 1 produced cubs at 4 years of age and 2 at 5 years of age (Table 5). The lack of females under 3 years old being in estrus, and because 2 of 3 monitored females did not produce cubs before age 5, suggests that most females throughout the study area were not reaching maturity until approximately 4.5 yrs.

Table 3. Comparison of black bear sex and age composition of bears captured on the White Mountain Study Area, Arizona with lightly exploited areas in central and north-central Arizona, and a heavily exploited area in north-central Arizona.

Location	MALES		FEMALES		TOTAL POPULATION	
	Percent ^a adults	Percent ^b subadults	Percent adults	Percent subadults	Percent adults	Percent subadults
White Mountains	59 (22) ^c	41 (15)	70 (16)	30 (7)	62 (37)	38 (23)
Central Arizona ^d	61 (20)	39 (13)	86 (19)	14 (3)	71 (39)	29 (16)
North-Central Arizona ^d	69 (11)	31 (5)	71 (12)	29 (5)	70 (23)	30 (10)
North-Central Arizona ^e	38 (11)	62 (18)	82 (9)	18 (2)	50 (20)	50 (20)

^aAdults = >3 years.

^bSubadults = 1 to 3 years.

^cNumber of individuals.

^dLightly exploited.

^eHeavily exploited.

Table 4. Percent of adult females in estrus from April through August on the White Mountain Study Area, Arizona, 1986-1989.

Month/Day	5/1-15	5/16-31	6/1-15	6/16-30	7/1-15	7/16-31	8/1-15
Percent in Estrus	0	50	100	75	100	25	0
Average Estrus Rating ^a	0 (0)	0.5 (2) ^b	3.3 (3)	2.3 (4)	2.0 (1)	0.8 (4)	0 (8)

^a0-4 rating with 4 being highest degree of estrus.^b() Sample size.

This minimum breeding age is higher than that found in both central and north-central Arizona (LeCount 1984, 1987), but is lower than values found in some other black bear populations (Jonkel and Cowen 1971, Beecham 1980, Kolenosky 1986, Rogers 1987). Maximum breeding age is unknown, but of the telemetered bears, the oldest female to produce cubs during the study was No.247, which produced 2 cubs at age 17 (Table 5).

Monitored adult females that produced cubs varied from 50 to 93% per year (Table 6). This dramatic difference in cub production appeared to be related to synchronous breeding of females in the population. Most female black bears do not produce their first litter of cubs until age 4 (Jonkel 1978). Also, during the time they are nursing cubs, normally they do not come into estrus (Erickson et al. 1964). Therefore, unless a female loses her cubs

Table 5. Reproductive history of 18 female black bears on the White Mountain Study Area, Arizona.

Bear No.	Cub Production (Survival)				
	Age ^a	1986	1987	1988 ^b	1989
189	2	0	0	1 (0)	2 (-) ^c
190	2	0	-	-	-
191	8	0	0	Cubs (0)	2 (-) ^c
192	3	0	0	2 (0)	3 (-) ^c
193	5	0	3 (3)	0	3 (-) ^c
194	8	2 (2)	0	Cubs (0)	2 (0)
196	3	-	0	0	2 (0)
197	4	-	2 (1)	0	2 (-) ^c
198	8	-	2 (2)	-	-
200	4	-	2 (2)	-	-
216	4	-	0	Cubs (0)	2 (0)
221	4	-	2 (2)	0	2 (-) ^c
235	10	-	-	Cubs (0)	2 (-) ^c
240	9	-	-	0	2 (1)
247	16	-	-	0	2 (0)
277	5	-	-	-	2 (-) ^c
278	9	-	-	-	0
280	4	-	-	-	1 (-) ^b

^aAge when first reproductive data collected.^bWhere the notation "cubs" appears, female was lactating but number of cubs was unknown.^cFinal fate of cubs unknown.

Table 6. Percent of telemetered adult females that produced cubs on the White Mountain Study Area, Arizona, 1987-1989.

Year	Number of Females		
	Breeding age ^a	With cubs	Percent females with litters
1987	7	5	71.4
1988	12	6	50.0
1989	15	14	93.3
Average			71.6 SE = 12.49

^aBreed age = >3 years.

before the end of the breeding season, she will only come into estrus and breed every other year. For example, in 1987, 5 of 7 breeding-age females that were monitored produced cubs. All successfully raised at least one of their cubs and so were not able to produce cubs in 1988 (Table 5). Consequently, only 6 of 12 breeding-age females produced cubs in 1988. All of these females lost their cubs before the end of the breeding season and, thus, were able to breed again in 1989, along with females that had produced cubs in 1987. As a result, 14 of 15 adult females produced cubs in 1989 (Table 5). Similar synchronous breeding has been reported from black bear populations in central Arizona (LeCount 1984), New York (Free and McCaffrey 1972), and Washington (Lindzey and Meslow 1977).

Litter size averaged 2.0 (SE = 0.10) in 22 observed litters, which is typical for Arizona (LeCount 1984, 1987) and most of western North America (Jonkel and Cowan 1971, Piekielek and Burton 1975, Lindzey and Meslow 1977, Beecham 1980). Eastern black bear litters normally exceed 2.0 (Bunnell and Tait 1981, Rogers 1987).

Of the 16 adult females captured, only 9 were successfully monitored for 2 or more years. A comparison of potential and actual reproduction of these 9 individuals suggested that cub production in this population was near biological potential. During this study, assuming an average litter size of 2 cubs and an average litter frequency of 2 years, there was a maximum potential for 13 (26 cubs) to be born (Table 7). Actual litters and cubs produced were 15 and 32, respectively. Two

Table 7. Comparison of reproductive potential and success of nine adult female black bears monitored for a minimum of 2 years on the White Mountain Study Area, Arizona.

Bear No.	Potential			Actual			Percent of Potential		
	Litters	Cubs born	Cubs raised	Litters	Cubs born	Cubs raised	Litters produced	Cubs produced	Cubs surviving
189	1	2	2	2	3	2	200.0	150.0	100.0
192	1	2	2	2	5	3	200.0	250.0	150.0
193	2	4	4	2	6	6	100.0	150.0	150.0
194	2	4	4	2	4	2	100.0	100.0	50.0
196	1	2	2	1	2	0	100.0	100.0	0.0
197	2	4	4	2	4	3	100.0	100.0	75.0
221	2	4	4	2	4	4	100.0	100.0	100.0
240	1	2	2	1	2	2	100.0	100.0	100.0
247	1	2	2	1	2	0	100.0	100.0	0.0
Total	13	26	26	15	32	22	115.4	123.1	84.6

factors contributed to the actual production being higher than the potential: some females produced 3-cub litters, and the loss of some litters before the end of the breeding season allowed other females to produce cubs in consecutive years (Table 5). This increased cub production also caused cub survival to be 85% of potential (Table 7) even though 31% of all tagged cubs died (Table 8).

Mortality

During this study 94 individual bears were marked, either as a result of summer capture

efforts or winter den work. Through December 1989, 25 (26%) of these 94 animals were known to have died: 10 cubs, 5 subadults, and 10 adults (Table 8). The calculated annual mortality rate for all bears in the population, except subadults, was 21% (Table 9).

Of the three age groups, cub mortality was the highest. Ten of 32 cubs (31%) died. Annual mortality averaged 34% (Table 10), which is higher than the 25 to 30% range documented for most North American black bears (Bunnell and Tait 1985). Hunters accounted for only 4% of annual cub mortality

Table 8. Documented causes of mortality of tagged bears on the White Mountain Study Area, Arizona, 1986-1989.

Age class	Total tagged	Mortalities		Causes of Mortality				
		Total	Percent	Hunting	Bear predation	Other predation	Accident	Capture
Cubs ^a	32	10	31.3	1	2	5	1	1
Subadults ^b	24 ^d	5	20.8	4	1	0	0	0
Adults ^c	38	10	26.3	8	1	0	0	1
Total	94	25	25.5	13	4	5	1	2

^aCub = <1 year.

^bSubadult = 1 to 3 years

^cAdults = >3 years to include two yearlings tagged in den.

^dSample size increased by two animals from Table 4 to include two yearlings tagged in den.

Table 9. Survival and mortality of adult and cub black bears during hunting and nonhunting periods on the White Mountain Study Area, Arizona, 1986-1989.

			Daily Rates			Interval Rates		
			Survival	Mortality		Survival	Mortality	
Interval	N days in interval	N bear days		hunt	other		hunt	other
Nonhunting Period	294	24026	0.9996	0.0000	0.0004	0.8848	0.0000	0.1152
Hunting Period	71	5104	0.9984	0.0016	0.0000	0.8946	0.1054	0.0000
Annual rates:						0.7915	0.0933	0.1152
95% confidence limits: Lower:						0.7104	0.0318	0.0481
Upper:						0.8820	0.1548	0.1823
Total annual mortality rate from all causes =								0.2085

Table 10. Survival and mortality of cub black bears during hunting and nonhunting periods on the White Mountain Study Area, Arizona, 1986-1989.

			Daily Rates			Interval Rates		
Interval	N days in interval	N bear days	Survival	Mortality		Survival	Mortality	
				hunt	other		hunt	other
Nonhunting Period	294	6535	0.9988	0.0000	0.0012	0.6975	0.0000	0.3024
Hunting Period	71	1254	0.9992	0.0008	0.0000	0.9449	0.0551	0.0000
Annual rates:						0.6592	0.0384	0.3024
95% confidence limits: Lower:						0.5016	0.0000	0.1283
Upper:						0.8662	0.1122	0.4765
Total annual mortality rate from all causes =								0.3408

(Table 10). The remainder was due to natural causes, with predation being the major factor. Mountain lions accounted for 50% of the total documented cub deaths and bear predation 20% (Table 8). All predation took place within 10 days of den emergence.

Larger litters appeared to be related to increased cub survival. Cub loss occurred in 8 of 22 (36%) litters monitored. Fifty percent of 1-cub litters, 41% of 2-cub litters, and no 3-cub litters experienced mortality. However, only 2 litters experienced partial litter loss. Among the remaining 20 litters, 14 experienced complete survival, whereas 6 had complete mortality (Table 5).

Cub mortality was also much higher in years when fewer adult females produced cubs. For example, in 1987 and 1989, 71 and 93% of all monitored adult females, respec-

tively, produced cubs, and during these years 91 and 69% of all cubs, respectively, survived. However, in 1988 when only half of all monitored adult females produced cubs, none survived (Table 11). A similar pattern of cub survival was also observed in central Arizona (LeCount 1984).

Bunnell and Tait (1985) estimated annual subadult mortality in black bear populations to be approximately 15-32%. In this study, average annual subadult mortality rates were not determined because few subadults were radio collared, but five tagged subadult deaths were documented. Eighty percent (4 of 5) of these deaths was caused by hunters. Only 1 subadult died of natural causes (Table 8). Whether these percentages are reflective of actual subadult mortality rates from various causes is not known. Certainly there was a

Table 11. Cub production and survival on the White Mountain Study Area, Arizona 1987-1989.

Year	Number of adult females monitored	Percent of adult females producing cubs	Total known cubs produced	Percent cubs surviving
1987	7	71.4 (5) ^a	11	90.0 (10) ^b
1988	12	50.0 (6)	3	0.0 (0)
1989	15	93.3 (14)	29	68.9 (20)

^a() Number of females.

^b() Number of cubs.

much greater chance of documenting hunting mortality through tag returns of killed bears than by accidentally finding bears dying of natural causes. Probably, actual subadult mortality that is due to hunting is lower than observed, and natural mortality is higher. Data from other studies indicate, however, that the majority of subadult mortality usually is due to hunting (Bunnell and Tait 1985, Kolenosky 1986). With the hunting pressure received by this population, one would suspect that hunting also would be the major cause of subadult mortality on the White Mountain study area.

Ten tagged adults died (Table 8), and the average annual mortality rate for adults was

15% (Table 12). Hunting accounted for most of all adult mortality, 12%, (Table 12). Of 16 adult females tagged, five (31%), were harvested by hunters over the 4 years of study. Only 4 of 22 tagged males (18%) were killed.

Of the 13 bears killed by hunters (Table 8) only 5 (2 subadult females, 1 adult female, 1 adult male, 1 female cub) were actually killed on the study area. Most others were killed within 10 miles of the study area in portions of Game Management Unit 27 where many bears moved to take advantage of fall mast crops. However, there were two notable exceptions: (1) an adult female (No. 200), tagged 3 years earlier, was shot approximately 100 miles west of the study area and (2) two 3-year old males (Nos. 201 and 273), were killed 80 miles

Table 12. Survival and mortality of adult male and female black bears during hunting and nonhunting periods on the White Mountain Study Area, Arizona, 1986-1989.

			Daily Rates			Interval Rates		
			Survival	Mortality		Survival	Mortality	
Interval	N days in interval	N bear days		hunt	other		hunt	other
ADULT MALES								
Nonhunting Period	294	3528	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000
Hunting Period	71	852	0.9977	0.0023	0.0000	0.8463	0.1537	0.0000
Annual rates:						0.8463	0.1537	0.0000
95% confidence limits: Lower:						0.6716	0.0000	0.0000
Upper:						1.0000	0.3494	0.0000
Total annual mortality rate from all causes =								0.1537
ADULT FEMALES								
Nonhunting Period	294	13963	0.9999	0.0000	0.0001	0.9588	0.0000	0.0412
Hunting Period	71	2998	0.9983	0.0017	0.0000	0.8882	0.1118	0.0000
Annual rates:						0.8516	0.1071	0.0412
95% confidence limits: Lower:						0.7560	0.0185	0.0000
Upper:						0.9594	0.1958	0.0972
Total annual mortality rate from all causes =								0.1483
ALL ADULTS								
Nonhunting Period	294	17491	0.9999	0.0000	0.0001	0.9669	0.0000	0.0331
Hunting Period	71	3850	0.9982	0.0018	0.0000	0.8788	0.1212	0.0000
Annual rates:						0.8497	0.1172	0.0331
95% confidence limits: Lower:						0.7639	0.0357	0.0000
Upper:						0.9542	0.1987	0.0781
Total annual mortality rate from all causes =								0.1503

southwest of the study area 2 years and 3 months, respectively, after tagging. All of these animals were killed in 1989, a year of severe drought in Arizona. These drought conditions caused many monitored bears to move long distances into areas where they had not previously been located. Whether these three animals had made similar drought-related movements or had become permanent residents in these areas is unclear because none were radio collared at the time of death.

In addition to the 5 tagged bears taken on the study area, 28 untagged bears (12 males, 12 females, 4 unclassified) were also harvested by hunters. Three (2 M, 1 F) of the 24 classified animals were adults and were killed before the area was thoroughly sampled.

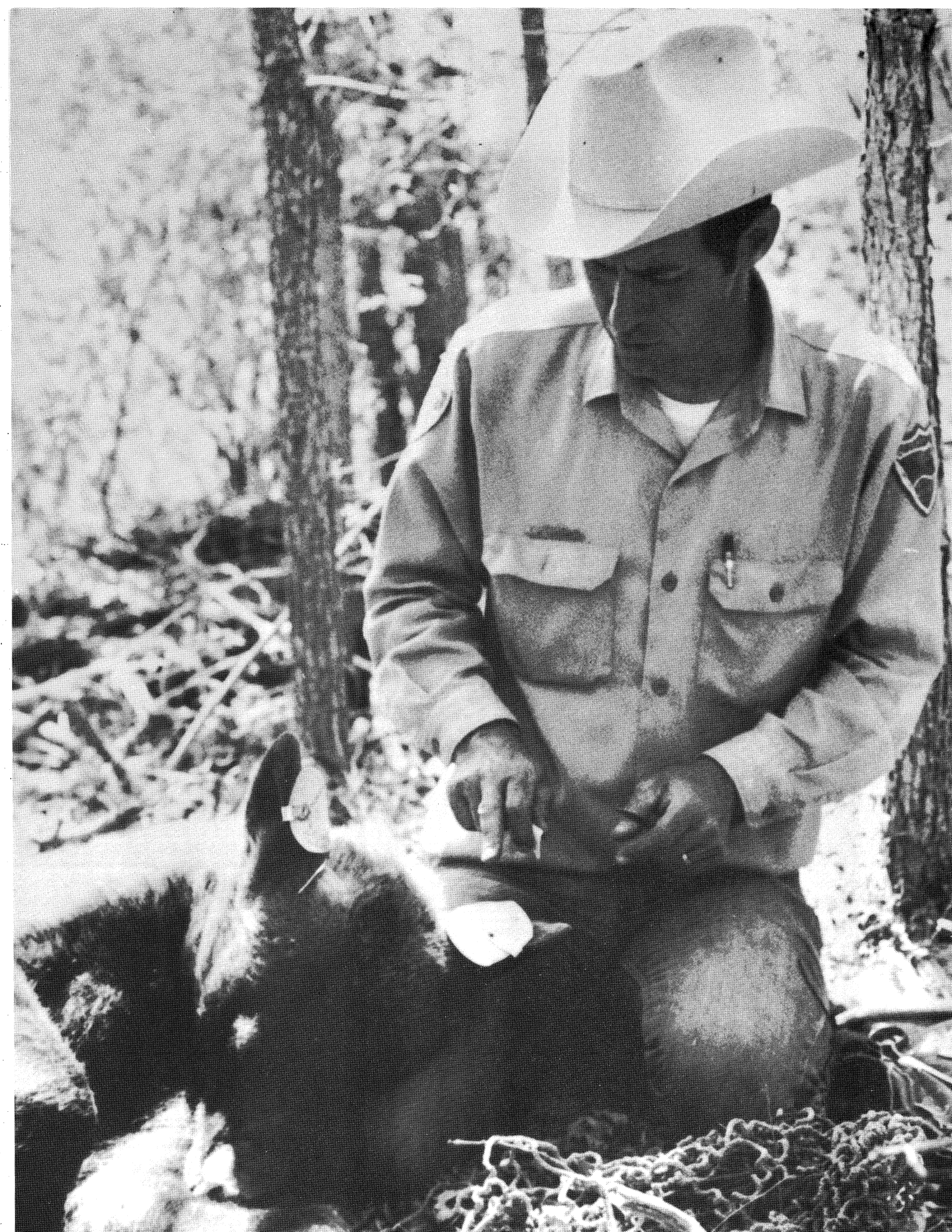
Of the 28 animals taken by hunters, 82% was taken during the first 2 weeks of the bear season by hunters hunting specifically for bears. The remainder was taken incidental to the hunting of other big game species, but this percentage varied greatly between years when baiting was legal and illegal (Table 13). A similar increase in incidental harvest also was observed throughout Unit 27 after baiting was discontinued (Table 13). During the time baiting was allowed, it was the hunting technique that produced the highest harvest, accounting for 13 of the 28 (46%) bears killed. Stalking and glassing was second highest, followed by predator calling and the use of dogs (Table 13).

Table 13. Percent of bears taken by various hunting techniques on the White Mountain Study Area and in Game Management Unit 27, Arizona, 1986-1989.

	Incidental (other game)	Stalking- glassing	Predator calling	Baiting	Dogs	Unknown	Total
Study Area							
1986	0.0 (0) ^a	0.0 (0)	0.0 (0)	50.0 (2)	0.0 (0)	50.0 (2)	4
1987	0.0 (0)	7.7 (1)	7.7 (1)	84.6 (11)	0.0 (0)	0.0 (0)	13
1988	50.0 (2)	0.0 (0)	0.0 (0)	-	50.0 (2)	0.0 (0)	4
1989	42.9 (3)	0.0 (0)	28.6 (2)	-	0.0 (0)	28.6 (2)	7
Total	17.9 (5)	3.6 (1)	10.7 (3)	46.4 (13)	7.1 (2)	14.3 (4)	28
Unit 27							
1986	16.7 (6)	0.0 (0)	0.0 (0)	16.7 (3)	33.3 (6)	16.7 (3)	18
1987	17.9 (10)	21.4 (12)	7.1 (4)	46.4 (26)	5.4 (3)	1.8 (1)	56
1988	34.5 (10)	31.0 (9)	3.4 (1)	-	24.2 (7)	6.9 (2)	29
1989	33.3 (13)	33.3 (13)	7.8 (3)	-	12.8 (5)	12.8 (5)	39
Total	27.5 (39)	23.9 (34)	5.6 (8)	20.4 (29)	14.8 (21)	7.8 (11)	142

^a()Number of animals.

*Following Page:
Ear tagging a black bear for future identification.*



DISCUSSION

Habitat quality is the ultimate limiting factor in determining black bear numbers, but factors such as habitat manipulation, nutrition, predation, or hunting can all be proximate regulation mechanisms (Lindzey and Meslow 1977, Beecham 1980, Hugie 1982, Young and Ruff 1982, Kolenosky 1986, LeCount 1987, Rogers 1987). In most populations, hunting is an important limiting factor because most wildlife agencies in North America attempt to manage bear populations for three general goals: control, conservation, or sustained yield (Miller 1990). These management principles are carried out by allowing hunters to take animals from the population. If removal is equal to recruitment, the population remains stable; if removal exceeds replacement, the population declines; if removal is below recruitment (and the population is below carrying capacity) the population increases. However in the latter case, if the population is at carrying capacity, adult bears keep the population stable by killing or evicting younger bears (Bunnell and Tait 1981).

The productivity of a bear population primarily is related to both habitat quality and the number of adult females in the population. Removal of adult females does not increase the productivity of the remaining females. Increased productivity can only be accomplished by the remaining females producing cubs at an earlier age, shortening the duration between litters, or by producing more cubs in each litter. The duration of all these factors is established through evolution with a specific forage base in the area and is beyond the control of an individual female (Bunnell and Tait 1981). Thus, the loss of females results in an overall decline in the breeding potential of the population until harvested females can be replaced by other reproductive females (Beecham 1980). For this replacement to occur, female cubs must be born, and survive to adulthood, in the area to which adult females are being removed. Replacement of harvested females cannot be achieved through ingress of subadult females from unhunted or

lightly exploited areas because few subadult females disperse from their place of birth (Hugie 1982, Rogers 1987).

Simulation modeling exercises and studies of hunted bear populations suggest that black bear populations cannot withstand total annual mortality rates of much over 17% (Bunnell and Tait 1981, Miller 1990). Indications of the degree of hunter exploitation on bear populations appear to be indicated by the sex and age structure of the population. In unhunted or lightly exploited populations, adults make up approximately 70% or more of the population, with sex ratios near 50:50 and mean ages ranging from 6 to 8 years. However, as populations are more heavily exploited, adult males are removed at a higher rate than adult females and are replaced by a higher number of subadult males than adult males removed. This results in adults making up 60% or less of the population, sex ratios become skewed toward males, and mean ages shift downward to 5 years or less (Kemp 1976, Beecham 1980, Kolenosky 1986, LeCount 1987, Rogers 1987). The consequences of this shift in the makeup of the population are that fewer reproductive females exist in the population and, because subadult females rarely disperse to new areas, the remaining females cannot produce enough new female offspring to replace females being killed. If this shift is not corrected, female numbers continue to decline until a reproductively viable population no longer exists.

Data from this study suggest that hunting may have been excessive. The area appeared to support a relatively high bear density, but sex and age structure data indicated only 62% of the population was adults, a percentage associated with highly exploited populations (Beecham 1980, Kolenosky 1986, LeCount 1987). Also, the mean age of 4.9 was near the 2.3 to 4.5 range reported for heavily harvested populations (Collins 1973, Lindzey et al. 1976, McCaffrey et al. 1976, Kolenosky 1986). Additionally, based on maximum sustainable mortality rates developed for black bears by Bunnell and Tait (1981), the 4.5 average age

of first reproduction and the annual natality rate of 1.0 indicate that this population was capable of supporting only a maximum sustainable annual mortality rate of 17%. Total annual mortality for cubs and adults was documented at 21% (Table 9); obviously if subadult mortality were added, the total annual mortality rate would substantially exceed the sustainable rate.

Exceeding the maximum sustainable mortality rate of any bear population should be of concern to managers for two reasons. First, that population is being overharvested rather than being managed on a sustained yield basis, which does not conform to Arizona Bear Strategic Plan objectives (Ariz. Game & Fish Dep. 1987). Second, overharvesting gradually reduces the number of resident breeding-age females, which, if continued, will eventually result in a significant reduction in resident bear numbers and hunting opportunity. Excessive harvest of adult females is of most concern because, as stated previously, the number of breeding-age females in a population is very important in

determining productivity of the population. As adult females are removed, the reproductive potential of the population is reduced until harvested females can be replaced by other reproductive females, which usually means female cubs must be born and survive to adulthood in the area. In some cases this recovery can take decades (Kolenosky 1986, Miller 1990) and, from the standpoint of lost hunting revenue, can be expensive.

Two factors, probably working together, appear to have been responsible for driving total and female harvest to high levels. One is increased hunter numbers and the other is the increased use of baiting as a hunting technique. In 1968, the Arizona Game and Fish Commission for the first time required that every person hunting a bear purchase a bear tag. This change caused the number of bear hunters to decline sharply in the early 1970s (Fig. 2). However, statewide bear harvest was not reduced to any degree because most of the hunters not purchasing tags were incidental bear hunters who only bought bear tags so that they could take a bear if they had the

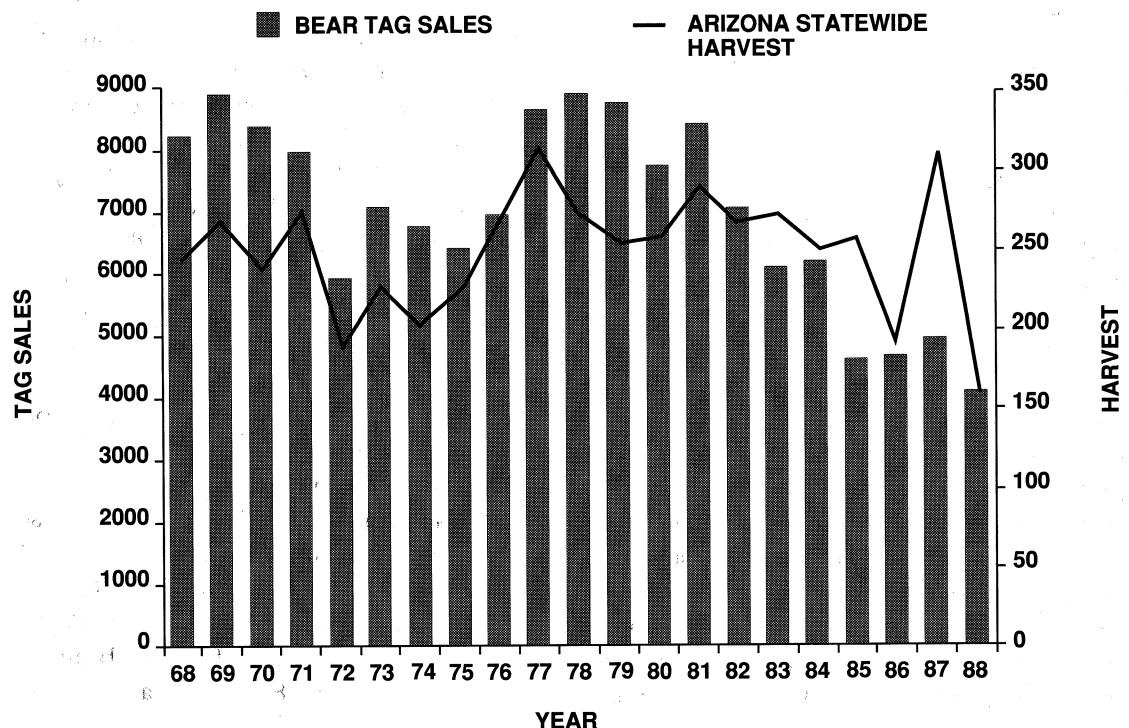


Figure 2. Number of bear tags purchased and annual bear harvest in Arizona, 1968-1988.

opportunity during another big game season (LeCount 1982a). During the late 1970s hunter numbers built back to late 1960s levels (Fig. 2), but because of restrictions of hunting opportunity for other species, a higher percentage of these hunters appeared to be hunting specifically for bears (LeCount 1982a). Even though data on methods of hunting were not collected, conversations with Arizona Game and Fish Department Wildlife Managers indicated that the general consensus was that many of these hunters started to use baiting as a hunting technique in the late 1970s. This combination of high hunter numbers, and the increased use of baiting as a hunting technique, pushed the statewide bear harvest to all time highs by the 1980s (Fig. 2).

Game Management Unit 27, which encompasses the White Mountain study area, seemed to reflect the statewide pattern. In Unit 27, and on the study area, the total number of bear hunters and the numbers using bait were not recorded each year, but they were thought to have increased in a pattern similar to that

observed throughout Arizona (Romero, Thompson, Ariz. Game and Fish Dep., pers. commun., Waddell, unpubl. data). The result of these increases was a dramatic increase in bear harvest.

In Management Unit 27 the annual bear harvest was variable, but a comparison of the annual harvest for the 8 years when hunter numbers were low and baiting an uncommon technique (1968-1975), with years when hunter numbers and the use of baits were high (1976-1987), showed a significant difference ($P = 0.003$) in the average harvest—from 21 to 36 bears per year (Fig. 3). This increased harvest appears to be related to increased hunters and the increased use of baiting rather than other variables between the two time periods (Romero, Thompson, Ariz. Game and Fish Dep., pers. commun., Waddell, unpubl. data). The only other variable that changed considerably during the two time periods was the climate. From the early 1970s to mid 1980s, total rainfall amounts in Arizona were higher than normal (Sellers et al. 1985).

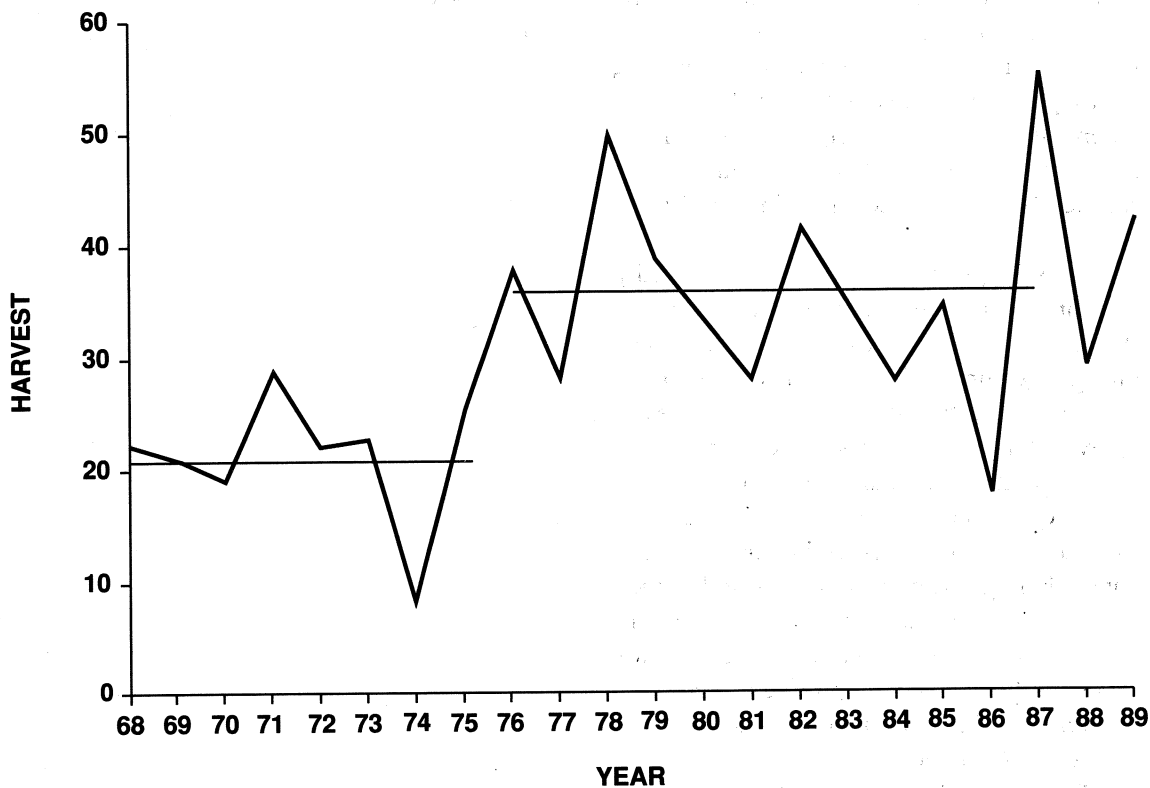


Figure 3. Game Management Unit 27 bear harvest, 1968-1989.

During the late 1980s, total moisture levels began to decline; by the last year of study (1989), the state was in a severe drought (Shaffer 1990). This drought caused bears to have difficulty finding adequate food supplies (LeCount and Yarchin 1990) and by late July, 1989, caused many to concentrate in lower elevations of Unit 27. Because these bears were concentrated in more open habitat than occurs on the study area and were stressed for food, they appeared to become more vulnerable to hunters. These conditions resulted in an inflated harvest of 39 bears for Unit 27 in 1989. In 1988, however, with more normal food supplies, the elimination of baiting, and reduced hunter numbers, only 29 bears were taken (Table 13).

A similar decrease in harvest, with the reduction of hunters and the elimination of baiting in 1988, was also observed on the study area. During the 4 years of study, 17 of the 28 (61%) bears harvested and 8 of 12 (67%) of the females reported killed were taken during the 2 years when hunter numbers were high and baiting was allowed (Table 13). Of these 8 females, all were taken with the use of baits, indicating that adult females were highly vulnerable to this hunting technique. During the last 2 years of study, when baiting was illegal and lower hunter numbers were observed, the total kill was reduced by 35% and the female harvest by 50%.

Thus, it appears that to maintain a healthy breeding bear population throughout the White mountains and in similar habitats, total and female annual mortality rates should not exceed 17%. Data collected in other studies show that if black bear populations are hunted to the extent that annual mortality exceeds that level, adult animals of both sexes removed are normally replaced by dispersing subadult males. The results of this replacement are a decline in adult numbers, a reduction in mean ages, sex ratios become skewed towards males, and a reduction in productivity occurs (Kemp 1976, Beecham 1980, Kolenosky 1986, LeCount 1987, Rogers 1987).

Data from this study indicate that the study area population was very close to fitting

the criteria of a highly exploited population and that annual mortality rates were in excess of those required to maintain a stable population. This mortality occurred in all segments of the population but was of particular importance in two: cubs (<1 year old) and adult females (>3 years old) because of its effect on recruitment. High adult female mortality (15% annually) reduced the number of older breeding-age females in the population, which in turn reduced the reproductive potential of the population. High cub mortality (34% annually) reduced the number of cubs available for replacement of killed adults. A reduction in mortality in either of these age classes would result in increased recruitment. From the management standpoint, however, it appears that the most practical approach to reducing total mortality would be to reduce adult female mortality because cub mortality primarily is due to natural causes, whereas adult mortality largely is due to human causes, namely hunting. Little can be done to reduce significantly the cub mortality, but by altering hunt structures both total adult mortality and, specifically, adult female mortality can be reduced.



Typical mixed-conifer forest that comprised a majority of the study area.

*Following Page:
Using calipers to measure head width of an adult male
black bear.*



MANAGEMENT OPTIONS

Attempts should be made to reduce harvest to total annual mortality rates that do not exceed 17%, which from the hunting mortality standpoint would be to reduce harvest to pre-1975 levels (approximately 20 bears/year). Equal sex ratios in the kill are indicative of overharvest (Bunnell and Tait 1985); therefore, the female portion of the kill should not make up more than 30%, which is consistent with Bear Strategic Plan objectives (Ariz. Game & Fish Dep. 1986). In trying to achieve this goal, however, managers should be aware that achieving a 70:30 sex ratio in the kill might meet the management goal but be inadequate to prevent overexploitation of the population if the majority of males killed are subadults. Therefore, mean ages should be monitored to determine if long term trends are toward older animals (6+). Several options appear to be available to accomplish these objectives.

Maintain Current Hunt Structure

Comparison of 1986-1987 harvest data, when baiting was allowed, with 1988-1989 data, when baiting was eliminated, shows that both overall harvest and female harvest was reduced by the elimination of baiting. Thus, it appears that maintenance of the 1988-1989 90-day nonbaiting hunt structure would keep the harvest at a level the population could sustain, while providing an unlimited number of hunters a high number of recreation days.

Move Baiting Season Dates

Even though data are not available on the number of hunters using baiting as a hunting technique, the decline in total and female harvest when this technique was eliminated suggests it to be both popular and efficient when used when females are active. If it is desirable to make baiting, plus all other common hunting techniques, available to an unlimited number of hunters during a 90-day season, then the 7-day baiting portion of the hunt should be moved into late November. By this time, many females have entered dens and are unavailable to hunters, yet males are still active (LeCount 1983, 1987). This alterna-

tive would lower the harvest level, give additional protection to females, allow hunters to use any hunting technique they desire, and allow an unlimited number of hunters a high number of recreation days.

Shorten Season Length

From the data collected during this study it appears that a 90-day bear season, with baiting being allowed during the first 7 days, results in an excessive harvest because the number of animals taken during the baiting portion of the season is close to the total harvest that the population can withstand for the year. Therefore, if a September opening date is desirable, with all common hunting techniques being legal, then the season should be shortened to no more than 7 days. Such a hunt structure would reduce harvest, let hunters use any hunting technique they desire, and allow an unlimited number of hunters an opportunity to go hunting. However, this hunt design would significantly reduce total recreational days.

Allow Bear Hunting By Permit Only

Permit hunting allows a great deal of flexibility in regulating both total and female harvest. Both season lengths and hunting techniques can be varied with the use of permits. If bear hunters prefer to have long seasons, and/or use effective hunting techniques, then permit numbers can be reduced to obtain the desired harvest. If more hunting opportunity is the management goal, permits can be increased, seasons shortened, and/or effective hunting techniques eliminated. This option would allow a restricted number of hunters to hunt with a variety of techniques during a variety of season lengths. Overall hunter opportunity, however, would be reduced.

Female Quotas

Quota, or point systems, similar to those used for waterfowl, are beginning to be used in mountain lion and bear hunts in some areas of North America to protect breeding-age females (Smith 1990). Both systems involve setting open ended seasons that do not close

until the prescribed quota has been harvested. This quota can either be a specific number of females, or a total point number derived from males and females, each of which is worth a designated number of points. Such a hunt system encourages hunters, especially guides, to take males rather than females because the more females killed the sooner the season will be closed. This management system allows an unrestricted numbers of hunters to use a variety of techniques. The number of recreational days will vary depending on how quickly the quota is reached, normally being smaller when the system is first implemented, and then increasing as hunters learn to select males. Increased expense for hunt management will be incurred by the Department to notify hunters of season closing dates.

Habitat Protection

It now appears that any of the above management options should keep the bear harvest within acceptable limits. However, these recommendations assume constant habitat conditions. Wildlife managers should keep in mind that habitat deterioration will reduce black bear carrying capacity. If this reduction occurs, managers and hunters will have to anticipate reductions in harvest and hunting opportunity to maintain reproductively healthy bear populations. Therefore, to assure good bear populations for future generations, both habitat and wildlife managers are encouraged to identify all bear habitat and to make every effort to maintain habitat quality and quantity.

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Key Words: black bear, *Ursus americanus*, population, age, ratios, reproduction, mortality.

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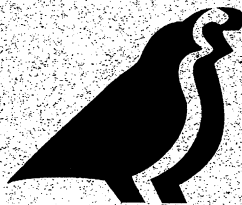
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